Armed Forces College of Medicine

AFCM

The Dead Space

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INTENDED LEARNING OBJECTIVES (ILO)

By the end of this lecture the student will be able to:

1. Define & list the types of dead space.
2. Enumerate factors that alter anatomical & physiologic dead spaces.
3. Explain the significance of anatomical dead space.
4. Explain the difference between pulmonary & alveolar ventilation.

The Dead Space

Def:

- It is the volume of air in the respiratory system which doesn't undergo gas exchange with blood.
- Normally = **150 ml**

Types:

Anatomical dead space.

It is the volume of air in the conducting airways, where no gas exchange occurs

Alveolar dead space.

It is the volume of air in the non functioning alveoli (non perfused alveoli)

Physiological dead space.

= anatomical D.S + alveolar D.S

The Dead Space

Physiological D.S = Anatomical D.S + Alveolar D.S

- Since normally in healthy individuals, nearly all the alveoli are functioning and amount of non-perfused alveoli are almost negligible so

The Physiological D.S = The Anatomical D.S

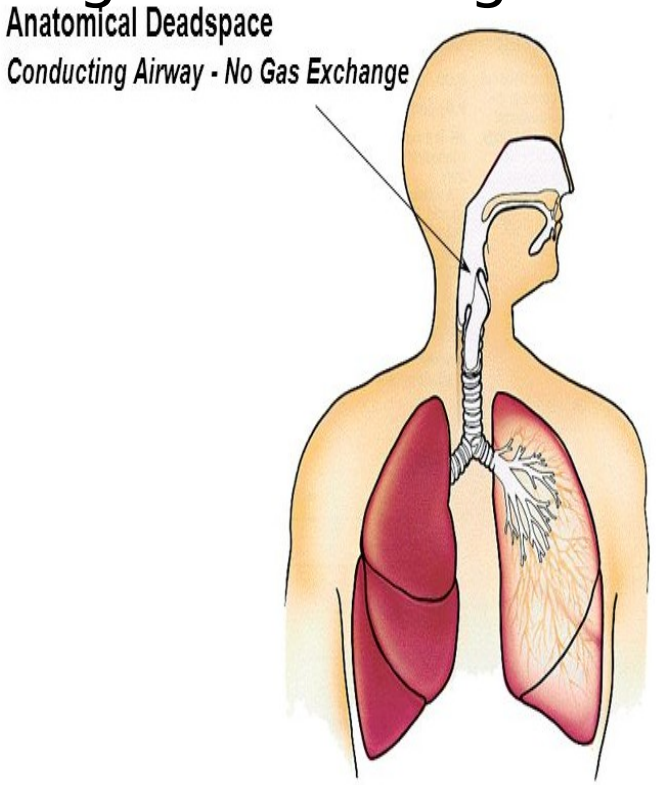
- The physiological D.S is increased in pathological conditions:

↑ The Physiological D.S > The Anatomical D.S

The Anatomical D.S The Alveolar D.S

Anatomical Dead Space

- It is the volume of air in the conducting airways (nasal cavity, pharynx, trachea, bronchi & terminal bronchioles) where no gas exchange takes place
- It is **increased** with
  - Upright position
  - Inspiration
  - Bronchodilation
  - Anesthesia
  - Drugs e.g B2 agor anticholinergic drugs



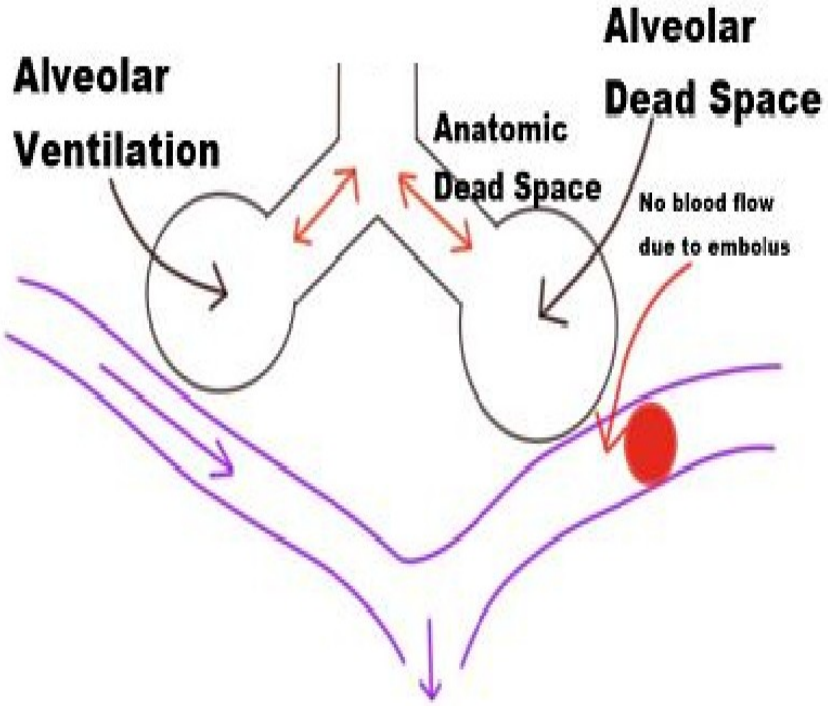
- It is **decreased** with
  - Supine position
  - Bronchoconstriction
  - Endotracheal intubatıon
  - Hypoxia
  - Histamine

Alveolar Dead Space

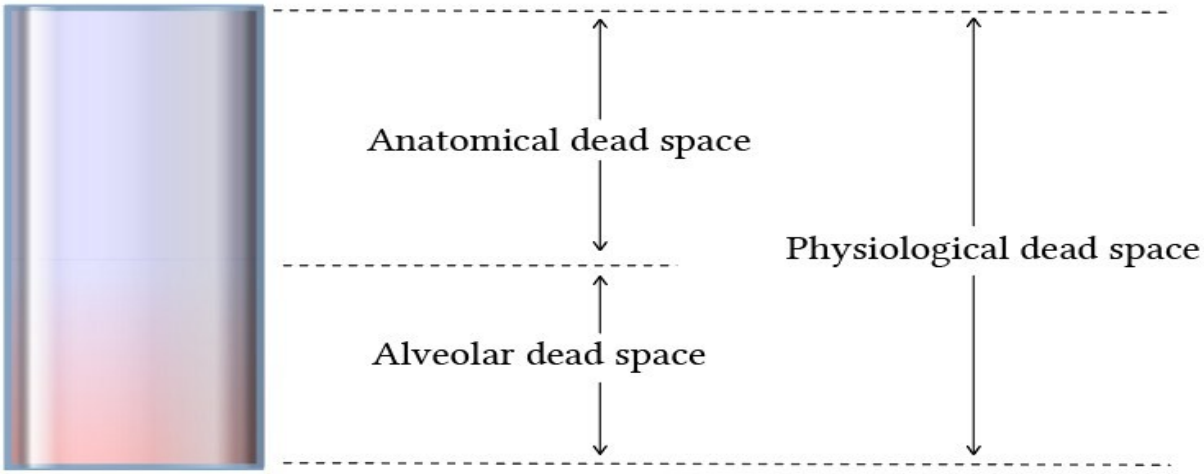
- It is the volume of air in non-perfused alveoli & thus not participating in gas exchange.

- In **healthy** individuals, alveolar dead space is negligible as almost all alveoli well perfused.

- It is **increased** in conditions of impaired pulmonary blood flow e.g pulmonary embolism

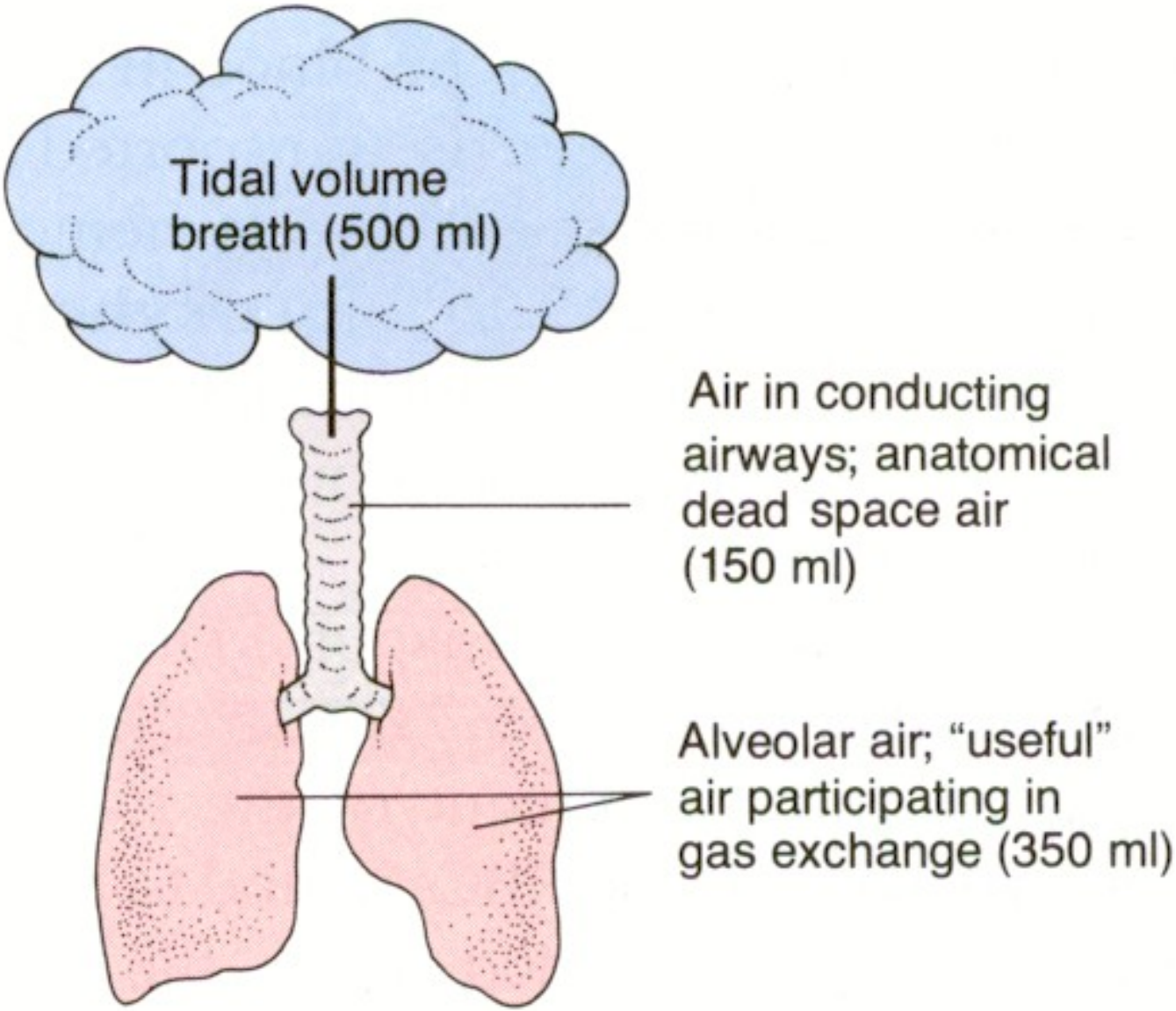


Physiological (total) Dead Space



- It is equals the anatomical DS plus alveolar DS.
- So under normal conditions, physiological DS & anatomical DS are nearly equal as all alveoli are functioning in normal lung.
- Under pathological conditions, physiological DS > anatomical DS
- Physiological DS **increased** by

1. ↑ in alveolar DS e.g non perfused alveoli d.t ↓ pulmonary blood


Tidal volume
breath (500 ml)
Air in conducting
airways; anatomical
dead space air
(150 ml)
Alveolar air; "useful"
air participating in
gas exchange (350 ml)

Significance of Dead Space

1. It is responsible for the difference between pulmonary ventilation & alveolar ventilation

ulmonary (minute) ventilat

of air that is inspired or expired in one minute dur

500 ml × **12/ min** = **6000 m**

monary (minute) ventilation = 600(

Significance of Dead Space

Alveolar ventilation

e of air that enters in gas exchange per minute duri

$$(500 - 150) \times 12 = 4200 \text{ ml}$$

Alveolar ventilation = 4200 ml

Significance of Dead Space

2. Because of the dead space, rapid shallow breathing produces much less alveolar ventilation than slow deep breathing at the same respiratory minute volume air.

Respiratory rate	30 /min	10 /min
Tidal volume	200 ml	600 ml
Minute volume	6 L	6 L
Alveolar ventilation	(200-150) X30 =1500ml	(600-150)x10 = 4500 ml

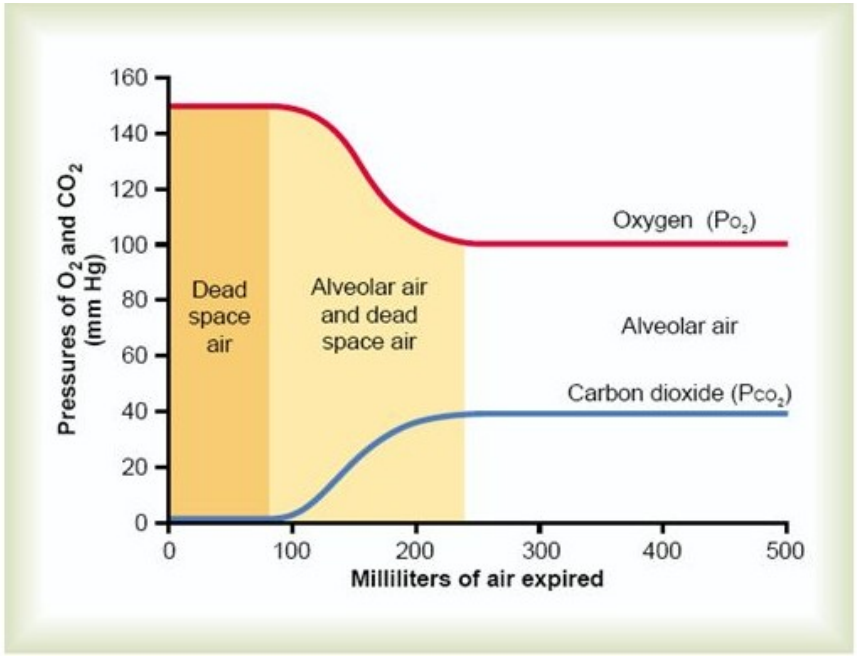
Note:

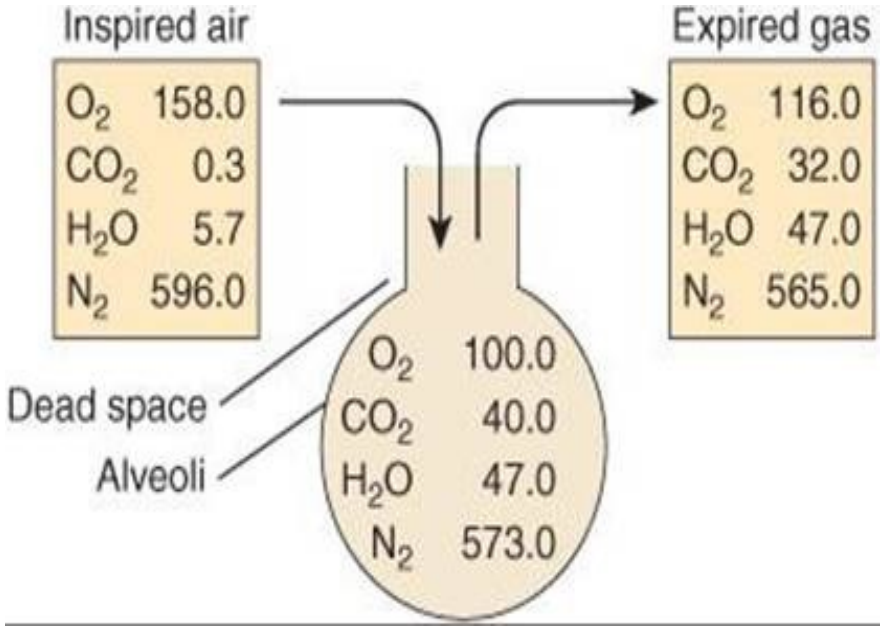
Calculation of alveolar ventilation is important in case of rapid shallow breathing as the tidal volume is decreased while the respiratory rate is increased. So the **pulmonary** ventilation may be normal while **alveolar** ventilation is markedly decreased

Significance of Dead Space

3. It is responsible for the difference between composition of **alveolar** air & **expired** air).

- Since expired air is a mixture of dead space (fresh atmospheric air) + alveolar air (old air)
- So expired air contains **higher** **PO2** and **lower** **PCO2** than alveolar air





Significance of Dead Space

4. Humidification & warming inspired air before reaching alveoli.

5. Protection of alveoli from damage by foreign particles &
bacteria (e.g filtration function of nose, mucous, sneezing&
coughing reflexes).

6. Phonation (production of sounds by vibration of vocal cords in
larynx by expired air).

7. Smell sensation as the nose contains olfactory receptors.

During Inspiration

Not all the inspired air (atmospheric) (tidal volume) (500 m
the site of gas exchange in the alveoli. Part of it remains in
airways, where it is not available for gas exchange

The volume of air occupying the conducting airways is called
space & averages 150 ml and

The remaining volume of air enters the alveoli = Tidal volu
= (500-1

end of inspiration, DS contains atmospheric air (fres

During Expiration

Expired air (tidal volume) **(500 ml)** gets out of the lungs

The first **150 ml** came from the dead space (atmospheric)

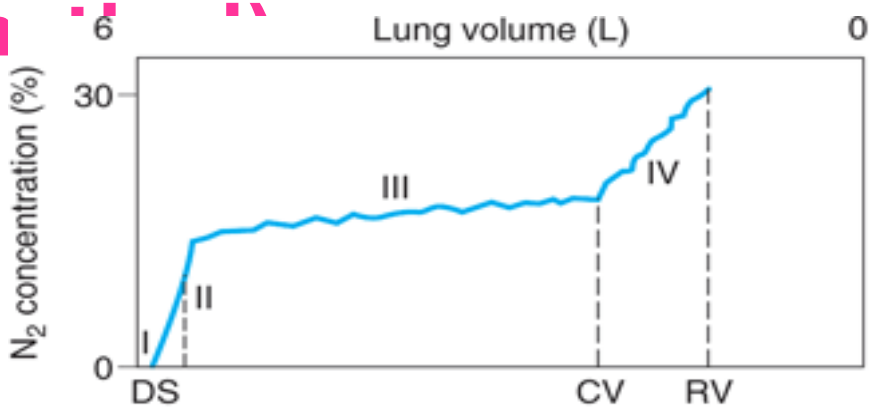
The next **350 ml** came from alveoli (alveolar air)

So as the expired air is a mixture of dead space (atmospheric air, it contains **more O2** & **less CO2** than alveolar air

the end of expiration, DS contains <u>alveolar</u> air (old air

Measurement of Dead Space

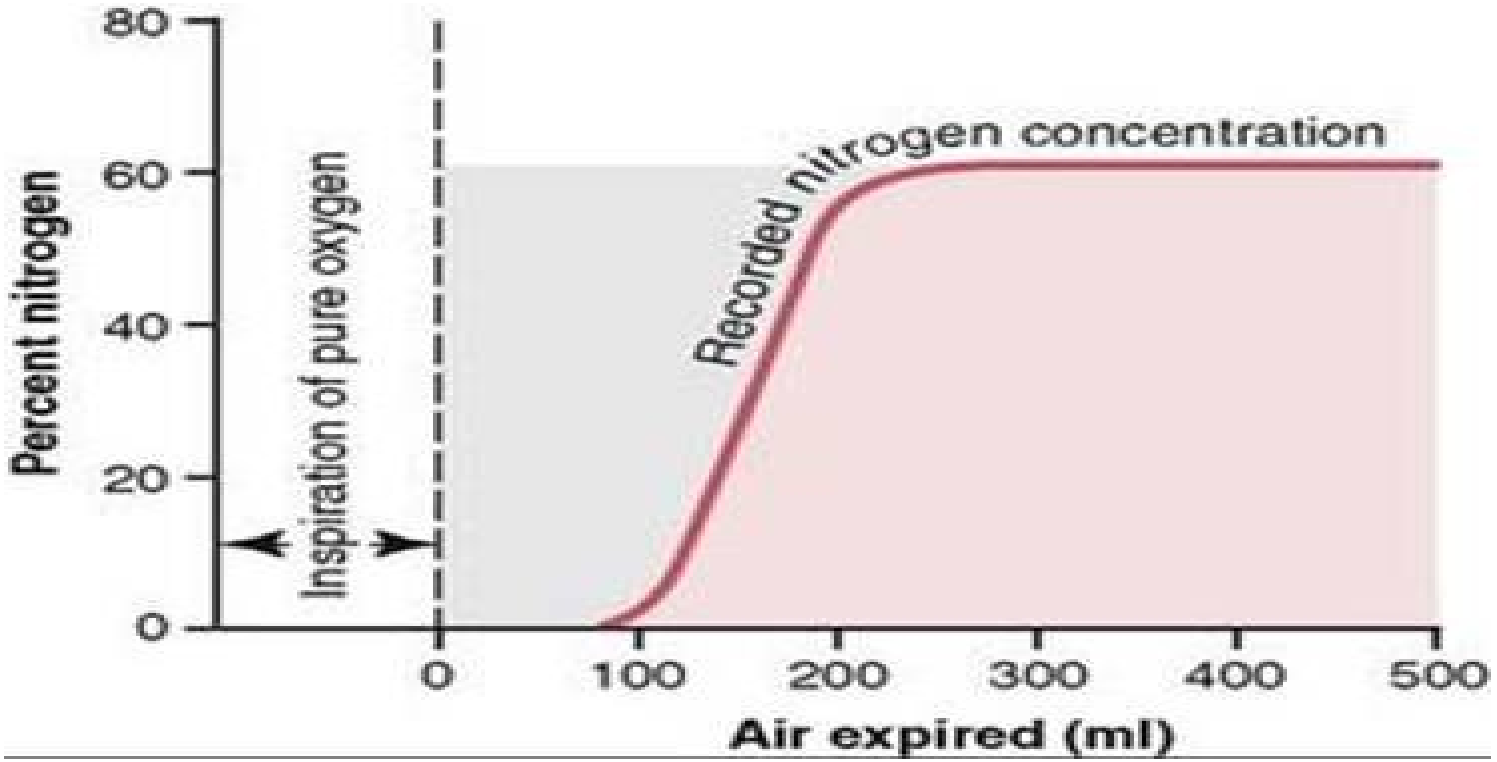
I. Single breath nitrogen test (Fowler m



Source: Barrett KE, Barman SM, Boitano S, Brooks H: *Ganong's Review of Medical Physiology, 23rd Edition*: http://www.accessmedicine.com

1. The subject takes as deep a breath of pure O_2.
2. He exhales steadily through a nitrogen meter so the N_2 content of the expired air is continuously measured.
3. The initial air exhaled (phase I) is the air that filled the dead space & contains no N_2. This is followed by a mixture of dead space & alveolar air (phase II) and then by alveolar air (phase III).
4. The volume of the dead space = phase I + mid portion of phase II

Measurement of Dead Space



The volume of the DS is
ume of air expired from peak inspiration to the mid-portion of p

Measurement of Dead Space

II. By Bohr's Equation

- The Physiological dead space is measured by this technique depending on the fact that the CO2 content of expired air is derived entirely from the alveolar air.

Dead Space = Tidal Volume × $\frac{\text{CO2\% in alveolar air - CO2\% in expired air}}{\text{CO2\% in alveolar air}}$

Example:

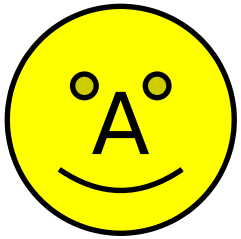
- If CO2% in expired air = 0.04 %
- If CO2% in alveolar air = 0.06 %
- Tidal volume (TV) = 500 ml

- **Thus dead space (DS)** = $\frac{0.06-0.04}{0.06}$ X 500 = **165** ml

Quiz

Q. A person who has a tidal volume of 400 ml, a respiratory rate of 14 and an anatomic dead space volume of 150 ml will have an alveolar ventilation rate of

A. 3,500 ml/minute.
B. 3,920 ml/minute.
C. 4,260 ml/minute.
D. 5,600 ml/minute.
E. 6,240 ml/minute.



Quiz

Q. When the tidal volume is 500 ml and the CO2 % in the expired air 0.03% and in the alveolar air 0.05%, the dead space would be:

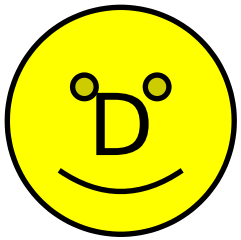
A. 50 ml

B. 150 ml

C. 250 ml

D. 200 ml

E. 100 ml



SUGGESTED TEXTBOOKS

1. Ganong's Review of Medical Physiology. 23rd edition , chapter 35, page (599-600)
2. Kaplan Medical USMLE step 1 lecture notes. Section VII, pages (147-150)


Thank You